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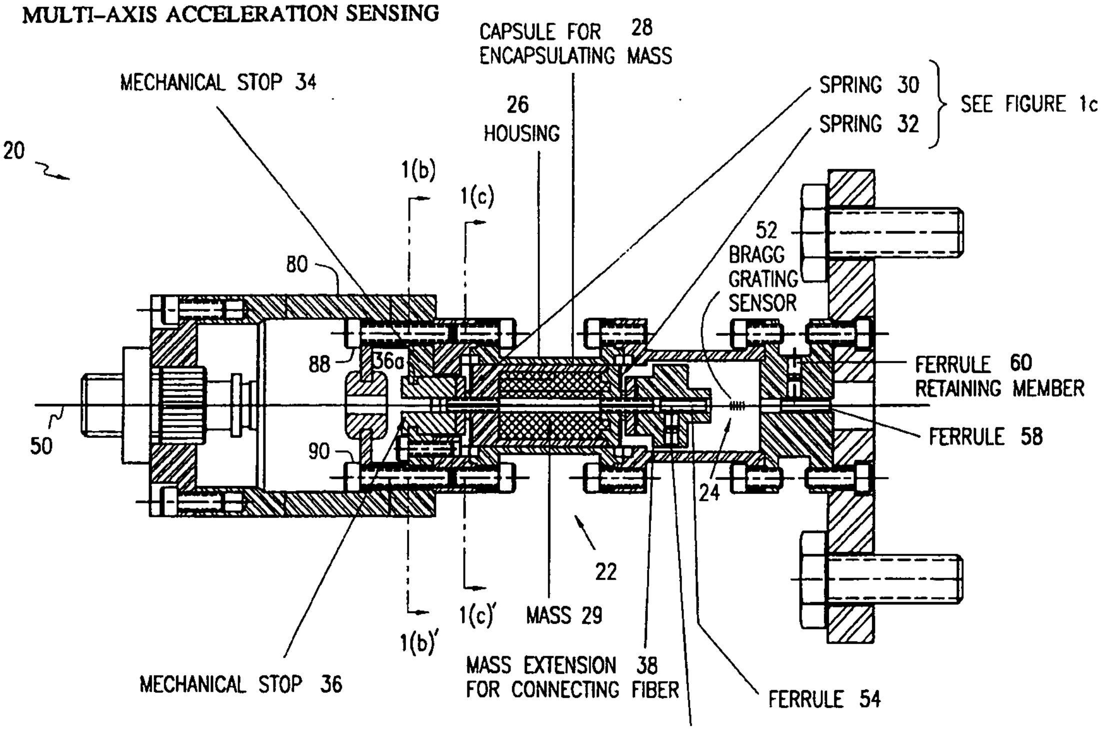

(57) **Abstract**

An accelerometer has a main body in combination with one or more Bragg grating sensors respectively arranged along one or more axes. The main body has a mass that responds to an acceleration in one or more axes. The compression or stretching of a Bragg grating sensor causes a wavelength shift in the optical signal that contains information about the acceleration and that is sensed by a detector.

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ACCELEROMETER FEATURING FIBER OPTIC BRAGG GRATING SENSOR FOR PROVIDING MULTIPLEXED MULTI-AXIS ACCELERATION SENSING

Technical Field

The present invention relates to an accelerometer; and more particularly, to an accelerometer using an optical fiber.

Background of Invention

Accelerometers are known in the prior art that use an optical fiber. Such accelerometers measure acceleration by sensing optical fiber surface strain, by sending optical fiber displacement or microbending, by sensing optical signal intensity, and by sensing optical signal phase shifts.

One disadvantage of the prior art accelerometers is that they are all complicated point sensors that do not allow multiplexing. Instead, a separate prior art accelerometer is needed to sense each respective axis.

Summary of Invention

In its broadest sense, the present invention provides an accelerometer comprising a main body in combination with a Bragg grating sensor means having an optical fiber with one or more Bragg grating sensors respectively arranged along one or more axes. The main body has a mass that responds to an acceleration, for providing a force having a component in one or more axes. The Bragg grating sensor means responds to the force, and further responds to an optical signal, for providing a Bragg grating sensor signal containing information about the acceleration respectively in one or more axes. The one or more axes may include orthogonal axes such as the X, Y and Z Euclidian axes.

The main body may include a proof mass and a spring means such as a pair of flexure disks, each having an inner ring, an outer ring, and radial splines connecting the inner ring and the outer ring. The proof mass is slidably arranged between the pair of flexure disks.

The Bragg grating sensor means includes an optical fiber having one or more Bragg grating sensors arranged therein.

In one embodiment, the optical fiber has a first end, a second end, and a Bragg grating sensor arranged between the first end and the second end. The first end of the Bragg grating sensor is fixedly coupled by a first ferrule to the proof mass. The second end of the Bragg grating sensor is fixedly coupled by a second ferrule to a housing of the accelerometer. The optical fiber is fixedly coupled to have a preloaded strain so that compression or stretching of the Bragg grating sensor causes a wavelength shift in the optical signal that contains information about the acceleration and that is sensed by a detector.

The Bragg grating sensor may include either a Bragg grating point sensor, multiple Bragg gratings, or a lasing element formed with pairs of multiple Bragg gratings.

One advantage of the present invention is that acceleration can be sensed using a single optical signal in a multiplexed manner, i.e. a single optical fiber having multiple Bragg grating sensors can be used to sense acceleration along multiple axes of an object.

The foregoing and other objects, features and advantages of the present invention will become more apparent in light of the following detailed description of exemplary embodiments thereof, as illustrated in the accompanying drawings.

Brief D scription of the Drawings

Figures 1a to 1d show various Figures related to an embodiment of an accelerometer of the present invention.

Figure 1a is a cross-section of the embodiment of the present invention.

Figure 1b is a cross-section of the embodiment shown in Figure 1 along lines 1b-1b′ (without the fiber).

Figure 1c is a cross-section of the embodiment shown in Figure 1 along lines 1c-1c′.

Figure 1d is a graph of an actual accelerometer output and a theoretical accelerometer output plotted as a function of frequency versus amplitude.

Figure 2 is a diagram of a piston accelerometer.

Figure 3a is a diagram showing a side view of an edge clamped diaphragm accelerometer.

Figure 3b is a diagram showing a top view of the edge clamped diaphragm accelerometer in Figure 3a along lines 3b-3b′.

Figure 4a is a diagram showing a side view of a center clamped diaphragm accelerometer.

Figure 4b is a diagram showing a top view of the center clamped diaphragm accelerometer shown in Figure 4a along lines 4b-4b′.

Figure 5a is a diagram showing a side view of a dual diaphragm - single mass accelerometer.

Figure 5b is a diagram showing a side view of the dual diaphragm - single mass accelerometer shown in Figure 5a along lines 5b-5b′.

Figure 6a is a diagram of a side view of one embodiment of a cantilever plate accelerometer.

Figure 6b is a diagram of a front view of another embodiment of a cantilever plate accelerometer.

Figure 6c is a diagram of a back view of the embodiment of the cantilever plate accelerometer shown in Figure 6b.

Figure 7a is a diagram of a side of one embodiment of a flextensional accelerometer.

Figure 7b is a diagram of a side of another embodiment of a flextensional accelerometer.

Figure 8 is a diagram of a side view of an accelerometer having a bellows design.

Figure 9 is a diagram of an accelerometer for sensing acceleration in three orthogonal axes.

Figure 10 is a diagram of an accelerometer for sensing acceleration in three parallel axes.

Figure 11 is a diagram of an accelerometer for sensing acceleration on a supported body in three orthogonal axes.

Detailed Description of the Invention

The Accelerometer Set Forth in Figures 1a to 1d

Figures 1a shows an accelerometer generally indicated as 20 having a main body generally indicated as 22 in combination with a Bragg grating sensor means generally indicated as 24. Any person skilled in the art such as a mechanical engineer would appreciate how the accelerometer 20 operates after viewing Figures 1a to 1c. In view of this, a brief description of the accelerometer 20 shown in Figures 1a to 1c is provided to assist the reader in understanding the operation of the most important components of the accelerometer 20 (In other words, every single nut and bolt shown in Figures 1a-1c is not assigned a reference numeral).

In Figure 1a, the main body 22 has a housing 26 having a capsule 28 for encapsulating a proof mass 29 that is slidably arranged in the housing 26. The main body 22 also has a spring means such as a pair of flexure disks 30, 32

arranged on each side of the proof mass 29. The pair of flexure disks 30, 32 are each fixedly coupled to the housing 26. The flexure disks 30, 32 are also fixedly coupled to the capsule 28 to allow slidable movement of the proof mass 29 in the housing 26. The flexure disks 30, 32 are shown in greater detail in Figure 1c.

On one side of the proof mass 29, the main body 22 has mechanical stops generally indicated as 34, 36 that cooperate for stopping the proof mass 29 at a maximum displacement to limit strain on the Bragg grating sensor means 24. On the other side of the proof mass 29, the main body 22 also has a mass extension 38 for connecting to the Bragg grating sensor means 24.

The Bragg grating sensor means 24 has an optical fiber 50 and one or more Bragg grating sensors 52 arranged therein. As shown, the fiber 50 passes completely through the accelerometer 20 and is connected on one fiber end to a light source (not shown), and on the other fiber end to a detector (not shown), as discussed in more detail below.

As shown, a first optical fiber end of the Bragg grating sensor 52 is fixedly coupled by a first ferrule 54 and a ferrule retaining member 56 to the mass extension 38 for connection to the proof mass 29. A second optical fiber end of the Bragg grating sensor is fixedly coupled by a second ferrule 58 and a ferrule retaining member 60 to the housing 26 of the accelerometer 20. As shown, the section of fiber fixedly coupled between the ferrules 54, 58 is about 4/10 of an inch in length, although the scope of the invention is not intended to be limited to any particular length. Moreover, the Bragg grating sensor 52 is fixedly coupled on its optical fiber ends to have a preloaded strain so that compression or stretching of the Bragg grating

sensor 52 causes a wavelength shift in an optical signal on the optical fiber 50 that contains information about the acceleration and that is sensed by a detector.

The ferrules 54, 58 may be made of glass or metal, or may also be welded to metallized fiber ends of the Bragg grating sensor, or may be glued to the ends of the Bragg grating sensor, or may be glass bonded to the first and second ends of the Bragg grating sensor.

In operation, the main body 22 and the proof mass 26 respond to an acceleration, for providing a force having a component in one or more axes. The Bragg grating sensor means 24 responds to the force, and further responds to an optical signal, for providing a Bragg grating sensor signal containing information about the acceleration respectively in one or more axes. The one or more axes may include orthogonal axes such as the X, Y and Z Euclidian axes.

In Figure 1b, the mechanical stop 34 is fixed to an extension of the housing 26 (Figure 1a) via three bolts 82 which allow the mechanical stop 34 to be rotated into place in relation to the mechanical stop 36. The mechanical stop 36 in Figure 1a has a groove 36a around the circumferences, and a set of three holes in the top section where the mechanical stop 34 can enter the mechanical stop 36. The mechanical stop 34 has three fingers 84 that line up with the groove 36a. Fingers 84 on the mechanical stop 34 slide into the groove 36 on the mechanical stop 36 and are rotated into place to limit the displacement of the seismic mass 29 (Figure 1a).

Figure 1c shows one of the flexure disks 30 in Figure 1a. As shown, the flexure disk 30 has an inner ring 70, an outer ring 72, and six radial splines generally indicated as 74 connecting the inner ring 70 and the outer ring 72. The

scope of the invention is not intended to be limited to any particular type of flexure disk.

The Signal Processing Circuitry

A person skilled in the art would appreciate how the optic fiber Bragg grating sensors are used as sensor elements. The reader is generally referred to United States Patent Serial Nos. 08/853,762; 08/853,535; and 08/853,402, all filed May 9,1997, all assigned to the assignee of the present application, and hereby incorporated by reference.

As described therein, a data acquisition unit has a broadband light source or laser diode with suitable photo optic couplers. Demodulators and filtering equipment can be used to monitor the Bragg grating wavelength shift as the grating is subjected to strain. If more than one grating is used, wave division multiplexing techniques can be utilized to discriminate the value or change in wavelength of each individual Bragg grating. The fiber optic connection between the acquisition unit and the washer is simply a length of fiber, and the actual decoding can be performed in a safe area if necessary. A readout device can be positioned so that a continuous reading of strain can be provided.

When such a fiber grating is illuminated, it reflects a narrow band of light at a specified wavelength. However, a measurand, such as strain induced by pressure or temperature, will induce a change in the fiber grating spacing, which changes the wavelength of the light it reflects. The value (magnitude) of the measurand is directly related to the wavelength reflected by the fiber grating and can be determined by detecting the wavelength of the reflected light.

Other optical signal analysis techniques may be us d with the present invention such as the necessary hardware and software to implement the optical signal diagnostic equipment disclosed in U.S. Patent Nos. 4,996,419; 5,361,130; 5,401,956; 5,426,297; and/or 5,493,390, all of which are hereby incorporated by reference.

As is well known in the art, there are various optical signal analysis approaches which may be utilized to analyze return signals from Bragg gratings. These approaches may be generally classified in the following four categories:

1. Direct spectroscopy utilizing conventional dispersive elements such as line gratings, prisms, etc., and a linear array of photo detector elements or a CCD array.
2. Passive optical filtering using both optics or a fiber device with wavelength-dependent transfer function, such as a WDM coupler.
3. Tracking using a tuneable filter such as, for example, a scanning Fabry-Perot filter, an acousto-optic filter such as the filter described in the above referenced U.S. Patent No. 5,493,390, or fiber Bragg grating based filters.
4. Interferometric detection.

The particular technique utilized will vary, and will depend on the Bragg wavelength shift magnitude (which depends on the sensor design) and the frequency range of the measurand to be detected. The scope of the invention is not intended to be limited to any particular optical signal analysis approach.

"Piston" Accelerometer in Figure 2

Figure 2 shows a "Piston" accelerometer generally indicated as 100 having a main body generally indicated as

102 and a Bragg grating sensor means generally indicated as 104.

The main body 102 has a housing 106 with a wall 108. The main body 102 also has a seismic mass 110 arranged on a spring rod 112 that responds to the acceleration along a single axis, for providing the force along the single axis.

The Bragg grating sensor mean 104 includes a first optical fiber 114, and a Bragg grating sensor 116 is connected on one end by a ferrule 120 to the seismic mass 110 and connected on the other end by a ferrule 122 to the wall 108 of the housing 106 of the accelerometer 100. In operation, the Bragg grating sensor 116 responds to an optical signal transmitted on the fiber 114, and further responds to the force provided by the seismic mass 110, for providing a Bragg grating sensor signal containing information about the acceleration along the single axis. Similar to that discussed above, the optical fiber 114 receives the optical signal light from a light source (not shown) and provides the Bragg grating sensor signal to a detector (not shown).

Edged Clamped Diaphragm-Mass Accelerometer in Figures 3a, 3b

Figures 3a and 3b show an edge clamped diaphragm-mass accelerometer generally indicated as 200 having a main body generally indicated as 202 and a Bragg grating sensor means generally indicated as 204.

In Figure 3a, the main body 202 has a housing 206 having a cylindrical wall 208, a removable bottom wall 210 and a removable top wall 212. The main body 202 also has a seismic mass 214 fixedly arranged on a diaphragm 216 having a circumferential edge generally indicated as 218 circumferentially clamped to the cylindrical wall 208. The scope of the invention is not intended to be limited to any

particular manner in which the seismic mass 214 is arranged on the diaphragm 216, or the diaphragm 216 is clamped to the cylindrical wall 208. In operation, the seismic mass 214 responds to an acceleration, for providing two forces each having a respective force component in one of two orthogonal axes.

The Bragg grating sensor means 204 includes one or more optical fibers 222, a first Bragg grating sensor 224 and a second Bragg grating sensor 226. As shown, the fiber 222 is a single fiber that passes through the seismic mass 214 and the diaphragm 216. The scope of the invention is not intended to be limited to the number of optical fibers such as optical fiber 222, because embodiments are envisioned where separate optical fibers may be used having separate Bragg grating sensors that receive separate optical signals and provide separate Bragg grating sensor signals.

The first Bragg grating sensor 224 is mounted between the seismic mass 214 and the removable bottom wall 210 and the removable top wall 212 of the housing 206 along one orthogonal axis by ferrules 228, 230, which are designed to retain the optical fiber 222 in a manner similar to the way ferrules 54, 58 retain the optical fiber 50 in Figure 1a. The first Bragg grating sensor 224 is typically prestrained in a manner similar to the Bragg grating sensor 52 in Figure 1a.

The second Bragg grating sensor 226 is embedded in or arranged on the diaphragm 216 between the clamped edge 218 and the seismic mass 214 along another orthogonal axis. The optical fiber 222 and the second Bragg grating sensor 226 may be either glued or epoxied onto the diaphragm 216. The scope of the invention is not intended to be limited to any particular physical connection between the optical fiber 222, the second Bragg grating sensor 226 and the diaphragm

216. In operation, the Bragg grating sensor means 204, including the first Bragg grating sensor 224 and the second Bragg grating sensor 226, responds to the two forces each having a respective force component in one of two orthogonal axes, and further responds to an optical signal along the optical fiber 222, for providing a Bragg grating signal containing information about the two forces acting on the seismic mass 214. Similar to that discussed above, the optical fiber receives the optical signal 222 light from a light source (not shown) and provides the Bragg grating sensor signal to a detector (not shown).

Further, the main body 202 also has a mechanical stop 232 arranged in an aperture generally indicated as 234 in the top housing wall 212. As shown, the top housing wall 212 has a circumferential rim 236, and the mechanical stop 232 has a corresponding circumferential channel generally indicated as 238 for receiving the circumferential rim 236. In operation, the mechanical stop 232 limits the movement of the seismic mass 214, that, in effect, limits the possible strain on the Bragg grating sensor 224 so it does break from overstretching. As shown, the optical fiber 222 passes through the mechanical stop 232 and is not fixedly retained therein. Any person skilled in the art would appreciate how to design the circumferential rim 236 of the top housing wall 212 in relation to the corresponding circumferential channel 238 of the mechanical stop 232 to achieve the desired tolerance to limit the possible strain on the Bragg grating sensor 224.

As shown in Figure 3b, the optical fiber 222 may pass through the cylindrical wall 208, although embodiments are envisioned in which the optical fiber 222 may pass though the bottom wall 210 or the top wall 212. The scope of the invention is not intended to be limited to any particular

manner in which the optic fiber 222 is passed through the main body 202 shown in Figures 8a, 8b.

Center Clamped Diaphragm Accelerometer in Figures 4a, 4b

Figures 4a, 4b show a center clamped diaphragm accelerometer generally indicated as 300 having a main body generally indicated as 302 and a Bragg grating sensor means generally indicated as 304.

In Figure 4(a), the main body 302 has a housing generally indicated as 305 having a cylindrical wall 306, a top wall 308, a removable bottom wall 310, and a center support 312. The main body 302 also has a diaphragm 314 fixedly arranged on the center support 312, and also has a circumferential seismic mass generally indicated as 316 arranged on a circumferential edge of the diaphragm 314. The scope of the invention is not intended to be limited to any particular manner in which the diaphragm 314 is arranged on the center support 312, or the circumferential seismic mass 316 is arranged on the circumferential edge of the diaphragm 314. Moreover, the scope of the invention is not intended to be limited to any particular shape of the seismic mass 316, which is described as being circumferential although embodiments are envisioned where the seismic mass 316 other shapes as well as including a plurality of masses arranged around the diaphragm 314. In operation, the seismic mass 316 responds to an acceleration, for providing two forces, each having a respective force component in one of two orthogonal axes.

The Bragg grating sensor means 304 includes an optical fiber 317, a first Bragg grating sensor 318 and a second Bragg grating sensor 320.

The first Bragg grating sensor 318 is mounted between the seismic mass 316 and the removable bottom wall 310 along

one orthogonal axis by ferrules 322, 324, which are designed to retain the optical fiber 317 in a manner similar to the way ferrules 54, 58 retain the optical fiber 50 in Figure 1a. The first Bragg grating sensor 318 is typically prestrained in a manner similar to the Bragg grating sensor 52 in Figure 1a.

The second Bragg grating sensor 320 is embedded in or arranged on the diaphragm 314 and mounted between the center support 312 and the seismic mass 316 along another orthogonal one axis. The optical fiber 317 and the second Bragg grating sensor 320 may be either glued or epoxied onto the diaphragm 314. The scope of the invention is not intended to be limited to any particular physical connection between the optical fiber 317, the second Bragg grating sensor 320, and the diaphragm 314. In operation, the Bragg grating sensor means 304, including the first Bragg grating sensor 318 and the second Bragg grating sensor 320, responds to the two forces each having a respective force component in one of two orthogonal axes, and further responds to an optical signal along the optical fiber 317, for providing a Bragg grating signal containing information about the two forces acting on the seismic mass 316. Similar to that discussed above, the optical fiber 317 receives the optical signal light from a light source (not shown) and provides the Bragg grating sensor signal to a detector (not shown).

Further, the main body 302 also has mechanical stops 330, 332, 334, 336 arranged around the cylindrical wall 306. As shown, the mechanical stop 330 has an upper stopping member 340 and a lower stopping member 342. The mechanical stops 332, 334 and 336 are similarly designed. In operation, the mechanical stop 330 limits the movement of the seismic mass 316, that, in effect, limits the possible strain on the Bragg grating sensor 318 so it does break from

overstretching. As shown, the optical fiber 317 passes through the upper stopping member 340 and the lower stopping member 342 and is not fixedly retained therein. Any person skilled in the art would appreciate how to design the mechanical stops 330, 332, 334, 336 in relation to the seismic mass 316 to achieve the desired tolerance to limit the possible strain on the Bragg grating sensor 318.

As shown in Figure 4b, the optical fiber 317 may pass through the cylindrical wall 306, although embodiments are envisioned in which the optical fiber 317 may pass though the top wall 308 or the removable bottom wall 310. The scope of the invention is not intended to be limited to any particular manner in which the optic fiber 317 is passed through the main body 302 shown in Figures 9a, 9b.

Dual Diaphragm, Single Mass Accelerometer in Figures 5a, 5b

Figures 5a, 5b show a dual diaphragm, single mass accelerometer generally indicated as 400 having a main body generally indicated as 402 and a Bragg grating sensor means generally indicated as 404.

In Figure 5a, the main body 402 has a housing generally indicated as 405 having a cylindrical housing wall 406 and a bottom wall 408. The main body 402 also has a seismic mass 410 fixedly arranged between two diaphragms 412, 414, each having a circumferential edge generally indicated as 416, 418 circumferentially clamped to the cylindrical wall 406. The scope of the invention is not intended to be limited to any particular manner in which the seismic mass 410 is arranged on the diaphragms 412, 414, or the diaphragms 412, 414 are clamped to the cylindrical wall 406. In operation, the seismic mass 410 responds to an acceleration, for

providing two forces each having a respective forc component in one of two orthogonal axes.

The Bragg grating sensor means 404 includes an optical fiber 420 and two Bragg grating sensors 422, 424.

The first Bragg grating sensor 422 is mounted between the seismic mass 410 and the bottom wall 408 along one orthogonal axis by ferrules 430, 432 which are designed to retain the optical fiber 222 in a manner similar to the way ferrules 54, 58 retain the optical fiber 50 in Figure 1a. The first Bragg grating sensor 422 is typically prestrained in a manner similar to the Bragg grating sensor 52 in Figure 1a.

The second Bragg grating sensor 424 is embedded in or arranged on one of the diaphragms such as the diaphragm 416 between the clamped edge 416 and the seismic mass 410 along another orthogonal axis. The optical fiber 420 and the second Bragg grating sensor 424 may be either glued or epoxied onto the diaphragm 416. The scope of the invention is not intended to be limited to any particular physical connection between the optical fiber 420, the second Bragg grating sensor 424 and the diaphragm 416. In operation, the Bragg grating sensor means 404, including the first Bragg grating sensor 422 and the second Bragg grating sensor 424, responds to the two forces each having a respective force component in one of two orthogonal axes, and further responds to an optical signal along the optical fiber 420, for providing a Bragg grating signal containing information about the two forces acting on the seismic mass 410. Similar to that discussed above, the optical fiber receives the optical signal 420 light from a light source (not shown) and provides the Bragg grating sensor signal to a detector (not shown).

Further, the main body 402 also has mechanical stops 440, 442 that limits the movement of the seismic mass 410 to limit the possible strain on the Bragg grating sensor 422 so it does break from overstretching. As shown, the optical fiber 420 passes through the mechanical stops 440, 442 and is not fixedly retained therein. Any person skilled in the art would appreciate how to design the mechanical stops 440, 442 to achieve the desired tolerance to limit the possible strain on the Bragg grating sensor 422.

As shown in Figure 5b, the optical fiber 420 may pass through the cylindrical wall 406, although embodiments are envisioned in which the optical fiber 420 may pass though the bottom wall 408. The scope of the invention is not intended to be limited to any particular manner in which the optic fiber 420 is passed through the main body 402 shown in Figures 10a, 10b.

Cantilever Plate Accelerometers in Figures 6a, 6b, 6c

Figures 6a shows a cantilever plate accelerometer generally indicated as 500 having a main body generally indicated as 502 and a Bragg grating sensor means generally indicated as 504.

In Figure 6a, the main body 502 has a housing generally indicated as 505 having a cylindrical housing wall 506 and a bottom wall 508. The main body 502 also has a seismic mass 510 fixedly arranged on the cylindrical housing wall 506. In operation, the seismic mass 510 responds to an acceleration, for providing a force along an axis.

The Bragg grating sensor means 504 includes an optical fiber 520 and a Bragg grating sensor 522.

The Bragg grating sensor 522 is mounted between the seismic mass 510 and the bottom wall 508 along an axis by ferrules 530, 532 which are designed to retain the optical

fiber 522 in a manner similar to the way ferrules 54, 58 retain the optical fiber 50 in Figure 1a. The Bragg grating sensor 522 is typically prestrained in a manner similar to the Bragg grating sensor 52 in Figure 1a.

Further, the main body 502 also has mechanical stops 540, 542 that limits the movement of the seismic mass 510 to limit the possible strain on the Bragg grating sensor 522 so it does break from overstretching. As shown, the optical fiber 520 passes through the mechanical stops 540, 542 and is not fixedly retained therein. Any person skilled in the art would appreciate how to design the mechanical stops 540, 542 to achieve the desired tolerance to limit the possible strain on the Bragg grating sensor 522.

As shown in Figure 6a, the optical fiber 520 may pass through the bottom wall 508, the seismic mass 510, and the mechanical stops 540, 542, although embodiments are envisioned in which the optical fiber 520 may pass though the wall 506. The scope of the invention is not intended to be limited to any particular manner in which the optic fiber 520 is passed through the main body 502 shown in Figures 6a.

Figures 6b and 6c show an alternative cantilever plate accelerometers generally indicated as 550, having a respective main body generally indicated as 552 and a respective Bragg grating sensor means generally indicated as 554.

In Figures 6b and 6c, the main body 552 has a housing generally indicated as 555 having a cylindrical housing wall 556. The main body 552 also has a seismic mass 560 fixedly arranged on a support member 561 connected to the cylindrical housing wall 556. In operation, the seismic mass 560 responds to an acceleration, for providing two forces each having a respective force component in one of two orthogonal axes.

As shown in Figure 6b, the Bragg grating sensor means 554 includes an optical fiber 570, a first Bragg grating sensor 572 and a second Bragg grating sensor 574.

The first Bragg grating sensor 572 and the second Bragg grating sensor 574 are embedded in or arranged on the support member 561. The scope of the invention is not intended to be limited to the position of the first and second Bragg grating sensor 572, 574 on the support member 561. The optical fiber 570 and the second Bragg grating sensor 574 may be either glued or epoxied onto the support member 561. In operation, the Bragg grating sensor means 554, including the first Bragg grating sensor 572 and the second Bragg grating sensor 574, responds to the two forces each having a respective force component in one of two orthogonal axes, and further responds to an optical signal along the optical fiber 570, for providing a Bragg grating signal containing information about the two forces acting on the seismic mass 560. Similar to that discussed above, the optical fiber receives the optical signal 570 light from a light source (not shown) and provides the Bragg grating sensor signal to a detector (not shown).

Flextensional Accelerometers in Figure 7a, 7b

Figures 7a shows a flextensional accelerometer generally indicated as 600 having a respective main body generally indicated as 602 and a respective Bragg grating sensor means generally indicated as 604.

In Figure 7a, the main body 602 has a housing generally indicated as 605 having side walls 606, 607 and top and bottom wall 608, 609. The main body 602 also has a seismic mass 610 fixedly arranged on flextension members 612, 614. In operation, the seismic mass 610 responds to an acceleration, for providing a force along an axis.

The Bragg grating sensor means 604 includes an optical fiber 620 and a Bragg grating sensor 622.

The Bragg grating sensor 622 is mounted between the flextensional members 612, 614 along the axis by ferrules 630, 632 which are designed to retain the optical fiber 622 in a manner similar to the way ferrules 54, 58 retain the optical fiber 50 in Figure 1a. The Bragg grating sensor 622 is typically prestrained in a manner similar to the Bragg grating sensor 52 in Figure 1a.

Further, the main body 602 also has mechanical stops 640, 642 that limits the movement of the seismic mass 610 to limit the possible strain on the Bragg grating sensor 622 so it does break from overstretching. Any person skilled in the art would appreciate how to design the mechanical stops 630, 632 to achieve the desired tolerance to limit the possible strain on the Bragg grating sensor 622.

As shown in Figure 7a, the optical fiber 620 may pass through the side walls 606, 607, although embodiments are envisioned in which the optical fiber 620 may pass though the top and bottom walls 608, 609. The scope of the invention is not intended to be limited to any particular manner in which the optic fiber 620 is passed through the main body 602 shown in Figures 7a.

Figures 7b shows an alternative design for a flextensional accelerometer generally indicated as 650 having a respective main body generally indicated as 652 and a respective Bragg grating sensor means generally indicated as 654.

In Figure 7b, the main body 652 has a housing generally indicated as 655 having side walls 656, 657 and top and bottom wall 658, 659. The main body 652 also has a seismic mass 660 fixedly arranged on flextension members 662, 664.

In operation, the seismic mass 660 responds to an acceleration, for providing a force along an axis.

The Bragg grating sensor means 654 includes an optical fiber 670 and a Bragg grating sensor 672.

The Bragg grating sensor 672 is mounted between the seismic mass 660 and the bottom wall 659 along the axis by ferrules 680, 682 which are designed to retain the optical fiber 672 in a manner similar to the way ferrules 54, 58 retain the optical fiber 50 in Figure 1a. The Bragg grating sensor 672 is typically prestrained in a manner similar to the Bragg grating sensor 52 in Figure 1a.

Further, the main body 652 also has mechanical stops 690, 692 that limits the movement of the seismic mass 660 to limit the possible strain on the Bragg grating sensor 672 so it does break from overstretching. Any person skilled in the art would appreciate how to design the mechanical stops 680, 682 to achieve the desired tolerance to limit the possible strain on the Bragg grating sensor 672.

As shown in Figure 7b, the optical fiber 670 may pass through the top and bottom walls 658, 659, although embodiments are envisioned in which the optical fiber 520 may pass though the side walls 656, 657. The scope of the invention is not intended to be limited to any particular manner in which the optic fiber 670 is passed through the main body 652 shown in Figures 7b.

A Bellows-like Accelerometer in Figure 8

Figure 8 shows an alternative design for a bellows-like accelerometer generally indicated as 700 having a main body generally indicated as 702 and a Bragg grating sensor means generally indicated as 704.

In Figure 8, the main body 702 has a housing generally indicated as 705 having side walls 706, 707 and top and

bottom walls 708, 709. The main body 702 also has a seismic mass 710 fixedly arranged on a bellows 712 having four convolutions 714. In operation, the seismic mass 710 responds to an acceleration, for providing a force along an axis.

The Bragg grating sensor means 704 includes an optical fiber 720 and a Bragg grating sensor 722.

The Bragg grating sensor 722 is mounted between the seismic mass 710 and the bottom wall 709 along the axis by ferrules 730, 732 which are designed to retain the optical fiber 672 in a manner similar to the way ferrules 54, 58 retain the optical fiber 50 in Figure 1a. The Bragg grating sensor 722 is typically prestrained in a manner similar to the Bragg grating sensor 52 in Figure 1a.

Further, the main body 702 also has uses the top wall 708 as one mechanical stop and also has another mechanical stop 740 that limits the movement of the seismic mass 710 to limit the possible strain on the Bragg grating sensor 722 so it does break from overstretching. Any person skilled in the art would appreciate how to design the mechanical stops 708, 740 to achieve the desired tolerance to limit the possible strain on the Bragg grating sensor 722.

A Three Orthogonal Axes Accelerometer in Figure 9

Figure 9 shows a three orthogonal axes accelerometer generally indicated as 800 having a main body generally indicated as 802 and a Bragg grating sensor means generally indicated as 804.

The main body 802 includes a supporting member 806 having three orthogonally-extending beams 808, 810, 812. The three orthogonally-extending beams 808, 810, 812 respond to the acceleration, for providing three forces, each having

a respective force component in one of three orthogonal axes.

The Bragg grating sensor means 804 includes an optical fiber 814 and three Bragg grating sensors 816, 818, 820. Each Bragg grating sensor 816, 818, 820 responds to a respective force, and each further responds to an optical signal, for providing three Bragg grating sensor signals containing information about a respective acceleration in the three orthogonal axes.

As shown, a first Bragg grating sensor 822 is embedded in or arranged on a first orthogonally-extending beam 808 along the X axis; a second Bragg grating sensor 824 is embedded in or arranged on a second orthogonally-extending beam 810 along the Y axis; and a third Bragg grating sensor 826 is embedded in or arranged on a third orthogonally-extending beam 812 along the Z axis. The scope of the invention is not intended to be limited to any particular physical connection between the optical fiber 814 and the three orthogonally-extending beams 808, 810, 812. Similar to that discussed above, the optical fiber receives the optical signal light from a light source (not shown) and provides the Bragg grating sensor signal to a detector (not shown).

A Three Parallel Axes Accelerometer in Figure 10

Figure 10 shows a three axis accelerometer generally indicated as 900 having a main body generally indicated as 902 and a Bragg grating sensor means generally indicated as 904.

The main body 902 has a seismic mass 906 having at least three legs 908, 910, 912 resting on a base 914. The seismic mass 906 responds to the acceleration of the base

914, for providing three forces, each having a respective force component in one of three axes.

The Bragg grating sensor means includes an optical fiber 916 and three Bragg grating sensors 918, 920, 922. Each Bragg grating sensor 918, 920, 922 responds to a respective force, and each further responds to the optical signal, for providing three Bragg grating sensor signals containing information about a respective acceleration in the three axes.

As shown, a first Bragg grating sensor 918 is embedded in or arranged on a first leg 908 along a first axis; a second Bragg grating sensor 920 is embedded in or arranged on a second leg 910 along a second axis; and a third Bragg grating sensor 922 is embedded in or arranged on a third leg 912 along a third axis. The optical fiber 916 passes through the seismic mass 906. The scope of the invention is not intended to be limited to any particular physical connection between the optical fiber 916 and the legs 908, 910, 912. Similar to that discussed above, the optical fiber receives the optical signal light from a light source (not shown) and provides the Bragg grating sensor signal to a detector (not shown).

A Second Three Orthogonal Axes Accelerometer in Figure 11

Figure 11 shows a three orthogonal axes accelerometer generally indicated as 1000 having a main body generally indicated as 1002 and a Bragg grating sensor means generally indicated as 1004.

The main body 1002 has a housing with six walls 1006, 1008, 1010, 1012, 1014, 1016. The main body also has a seismic mass 1018 connected by six legs 1020, 1022, 1024, 1026, 1028, 1030 to the six walls 1006, 1008, 1010, 1012, 1014, 1016. The seismic mass 1018 responds to the

acceleration, for providing a force having a component in one of three axes.

The Bragg grating sensor means 1004 includes an optical fiber 1032 and three or more Bragg grating sensors 1040, 1042, 1044. Each Bragg grating sensor 1040, 1042, 1044 responds to the force, and each further responds to an optical signal transmitted on the optical fiber 1032, for providing three or more Bragg grating sensor signals containing information about a respective acceleration in the three axes.

A first Bragg grating sensor 1040 is embedded in or arranged on a first leg 1020 along a first axis; a second Bragg grating sensor 1042 is embedded in or arranged on a second leg 1022 along a second axis; and a third Bragg grating sensor 1044 is embedded in or arranged on a third leg 1046 along a third axis. Embodiments are also envisioned wherein the fourth, fifth and sixth legs have Bragg grating sensors, as well. Moreover, the scope of the invention is not intended to be limited to any particular physical connection between the optical fiber 1032 and the legs 1020, 1022, 1024. Similar to that discussed above, the optical fiber receives the optical signal light from a light source (not shown) and provides the Bragg grating sensor signal to a detector (not shown).

Scope of the Invention

Although the invention has been described and illustrated with respect to exemplary embodiments thereof, the foregoing and various other additions and omissions may be made therein and thereto without departing from the spirit and scope of the present invention.

WE CLAIM:

1. An accelerometer, comprising:

a main body, responsive to an acceleration, for providing a force having a component in one or more axes; and

Bragg grating sensor means, responsive to the force, and further responsive to an optical signal, for providing a Bragg grating sensor signal containing information about the acceleration respectively along the one or more axes.

2. An accelerometer according to claim 1, wherein the main body comprises:

a proof mass, responsive to the acceleration, for providing a proof mass force; and

a spring means, responsive to the proof mass force, for providing a spring force corresponding to the proof mass force.

3. An accelerometer according to claim 1, wherein the Bragg grating sensor means comprises an optical fiber having one or more Bragg sensors arranged therein.

4. An accelerometer according to claim 1, wherein the spring means includes a pair of flexure disks, each having an inner ring, an outer ring, and radial splines connecting the inner ring and the outer ring.

5. An accelerometer according to claim 4, wherein the mass is arranged between the pair of flexure disks.

6. An accelerometer according to claim 5,

wherein the accelerometer includes a housing;

wherein the pair of flexure disks are each fixedly coupled to the housing;

wherein the proof mass means includes a capsule for encapsulating the mass; and

wherein the flexure disks are fixedly coupled to the capsule to allow slidable movement of the capsule in the housing.

7. An accelerometer according to claim 1,

wherein the main body includes a housing;

wherein the main body includes a proof mass;

wherein the proof mass means is slidably arranged in the housing;

wherein the Bragg grating sensor means includes an optical fiber having a Bragg grating sensor arranged therein;

wherein the first end of the Bragg grating sensor is fixedly coupled by a first ferrule to the proof mass;

wherein the second end of the Bragg grating sensor is fixedly coupled by a second ferrule to the housing; and

wherein the optical fiber is fixedly coupled to have a preloaded strain so that compression or stretching of the Bragg grating sensor causes a wavelength shift in the optical signal that contains information about the acceleration and that is sensed by a detector.

8. An accelerometer according to claim 7,

wherein the first ferrule and the second ferrule are made of glass or metal.

9. An accelerometer according to claim 8, wherein the first ferrule and the second ferrule are welded to metallized fiber ends of the Bragg grating sensor, are glued to the first and second ends of the Bragg grating sensor, or are glass bonded to the first and second ends of the Bragg grating sensor.

10. An accelerometer according to claim 2,

wherein the main body includes at least one mechanical stop for stopping the proof mass means at a maximum displacement to limit strain on the Bragg grating sensor means.

11. An accelerometer according to claim 1,

wherein the Bragg grating sensor includes either a Bragg grating point sensor, multiple Bragg gratings, or a lasing element formed with pairs of multiple Bragg gratings.

12. An accelerometer, comprising:

a main body having a member that is responsive to an acceleration, for providing a force having a force component in one or more orthogonal axes including an X axis, a Y axis and a Z axis; and

a Bragg grating sensor means, responsive to the force, and further responsive to an optical signal, for providing one or more Bragg grating sensor signals containing information about the acceleration in the one or more orthogonal axes.

13. An accelerometer according to claim 12,

wherein the accelerometer is a piston accelerometer;

wherein the main body has a housing with a wall;

wherein the main body includes a seismic mass arranged on a spring rod, responsive to the acceleration along a single axis, for providing the force having the force component in one of the orthogonal axes; and

wherein the Bragg grating sensor means includes a Bragg grating sensor arranged between the seismic mass and the wall of the housing of the accelerometer, the Bragg grating sensor responds to the optical signal, and further responds to the force, for providing a Bragg grating sensor signal containing information about the acceleration along the single axis.

14. An accelerometer according to claim 12,

wherein the accelerometer is an edge clamped diaphragm-mass accelerometer;

wherein the main body has a housing with a wall;

wherein the main body includes a seismic mass arranged on a diaphragm having clamped edges, the seismic mass being responsive to the acceleration, for providing two forces each having a respective force component in one of two orthogonal axes; and

wherein Bragg grating sensor means includes an optical fiber and two Bragg grating sensors, each responsive to a respective force, and each further responsive to the optical signal, for providing two Bragg grating sensor signals containing information about a respective acceleration in the two orthogonal axes.

15. An accelerometer according to claim 14,

wherein a first Bragg grating sensor is fixedly mounted between the seismic mass and the wall of the housing along one axis; and

wherein a second Bragg grating sensor is embedded in or glued onto the diaphragm.

16. An accelerometer according to claim 12,

wherein the accelerometer is a center clamped diaphragm accelerometer;

wherein the main body includes a support with two walls;

wherein the main body includes a diaphragm arranged on a center support, and includes a seismic mass arranged on an end of the diaphragm, the seismic mass being responsive to the acceleration, for providing two forces, each having a respective force component in one of two orthogonal axes; and

wherein Bragg grating sensor means includes an optical fiber and two Bragg grating sensors, each responsive to a respective force, and each further responsive to the optical signal, for providing two Bragg grating sensor signals containing information about a respective acceleration in the two orthogonal axes.

17. An accelerometer according to claim 16,

wherein a first Bragg grating sensor is embedded in or arranged on the diaphragm; and

wherein a second Bragg grating sensor is fixed mounted between a second wall of the support and the seismic mass along another axis.

18. An accelerometer according to claim 12,

wherein the accelerometer is a dual diaphragm, single mass accelerometer;

wherein the main body has a housing with two walls;

wherein the main body includes a seismic mass arranged between two diaphragms having clamped edges, the seismic mass being responsive to the acceleration, for providing four forces, each having a respective force component in one of two orthogonal axes; and

wherein Bragg grating sensor means includes an optical fiber and four Bragg grating sensors, each responsive to a respective force, and each further responsive to the optical signal, for providing four Bragg grating sensor signals containing information about a respective acceleration in the two orthogonal axes.

19. An accelerometer according to claim 18,

wherein a first Bragg grating sensor is embedded in or arranged on an upper diaphragm; and

wherein a second Bragg grating sensor is fixedly mounted between the seismic mass and the bottom wall of the housing.

20. An accelerometer according to claim 12,

wherein the accelerometer is a cantilever plate accelerometer;

wherein the main body has a housing with a wall;

wherein the main body includes a seismic mass arranged on a cantilever plate, the seismic mass being responsive to the acceleration, for providing a force in an axis; and

wherein Bragg grating sensor means includes an optical fiber and a Bragg grating sensor, responsive to the force, and further responsive to the optical signal, for providing

the Bragg grating sensor signal containing information about the acceleration in the axis.

21. An accelerometer according to claim 20,

wherein the Bragg grating sensor is fixedly mounted between the bottom wall of the housing and the seismic mass along another axis.

22. An accelerometer according to claim 12,

wherein the accelerometer is a flextensional accelerometer;

wherein the main body includes a seismic mass arranged in contact with flextensional members in which a contraction force along a first axis causes an expansion force along a second axis, the seismic mass being responsive to the acceleration, for providing a force the another axis; and

wherein Bragg grating sensor means includes an optical fiber and a Bragg grating sensor arranged in the flextensional means, the Bragg grating sensor means being responsive to the force, and each further responsive to the optical signal, for providing the Bragg grating sensor signal containing information about the acceleration in the second axis.

23. An accelerometer according to claim 12,

wherein the accelerometer is a flextensional accelerometer;

wherein the main body includes a seismic mass arranged in contact with flextensional members in which a contraction force along an axis causes an expansion force along another axis, the seismic mass being responsive to the acceleration, for providing a force the axis; and

wherein Bragg grating sensor means includes an optical fiber and a Bragg grating sensor arranged in the flextensional means, the Bragg grating sensor means being responsive to the force, and each further responsive to the optical signal, for providing the Bragg grating sensor signal containing information about the acceleration in the axis.

24. An accelerometer according to claim 12,

wherein the accelerometer is a bellows accelerometer;

wherein the main body includes a seismic mass arranged on a bellows-like means, the seismic mass being responsive to the acceleration, for providing a seismic mass force, having a force component in an axis; and

wherein Bragg grating sensor means includes an optical fiber and a Bragg grating sensor arranged in the bellows-like means, the Bragg grating sensor means being responsive to the proof mass force, and each further being responsive to the optical signal, for providing the Bragg grating sensor signal containing information about the component force of the acceleration in the axis.

25. An accelerometer according to claim 12,

wherein the accelerometer is a three axis accelerometer;

wherein the main body includes three orthogonally-extending beams, the three orthogonally-extending beams being responsive to the acceleration, for providing three forces, each having a respective force component in one of three orthogonal axes; and

wherein Bragg grating sensor means includes an optical fiber and three Bragg grating sensors, each responsive to a respective force, and each further responsive to the optical

signal, for providing three Bragg grating sensor signals containing information about a respective acceleration in the three orthogonal axes.

26. An accelerometer according to claim 25,

wherein a first Bragg grating sensor is embedded in or arranged on a first orthogonally-extending beam along the X axis;

wherein a second Bragg grating sensor is embedded in or arranged on a second orthogonally-extending beam along the Y axis; and

wherein a third Bragg grating sensor is embedded in or arranged on a third orthogonally-extending beam along the Z axis.

27. An accelerometer according to claim 12,

wherein the accelerometer is a three axis accelerometer for sensing acceleration of a base;

wherein the main body includes a seismic mass having at least three legs resting on a base, the seismic mass being responsive to the acceleration of the base, for providing three forces, each having a respective force component in one of three axes; and

wherein Bragg grating sensor means includes an optical fiber and three Bragg grating sensors, each responsive to a respective force, and each further responsive to the optical signal, for providing three Bragg grating sensor signals containing information about a respective acceleration in the three axes.

28. An accelerometer according to claim 27,

wherein a first Bragg grating sensor is embedded in or arranged on a first leg along a first axis;

wherein a second Bragg grating sensor is embedded in or arranged on a second leg along a second axis; and

wherein a third Bragg grating sensor is embedded in or arranged on a third leg along a third axis.

29. An accelerometer according to claim 12,

wherein the accelerometer is a three axes accelerometer;

wherein the main body includes a seismic mass suspended in a housing having six walls;

wherein the seismic mass is connected by six legs to the six walls of the housing, the seismic mass being responsive to the acceleration, for providing six forces, each having a respective force component in one of three axes; and

wherein Bragg grating sensor means includes an optical fiber and six Bragg grating sensors, each responsive to a respective force, and each further responsive to the optical signal, for providing six Bragg grating sensor signals containing information about a respective acceleration in the three axes.

30. An accelerometer according to claim 29,

wherein a first Bragg grating sensor is embedded in or arranged on a first leg along a first axis;

wherein a second Bragg grating sensor is embedded in or arranged on a second leg along a second axis; and

wherein a third Bragg grating sensor is embedded in or arranged on a third leg along a third axis.

31. An accelerometer, comprising:

a housing;

a main body having a housing and a mass arranged between a pair of flexure disks, each of the pair of flexure disks fixedly coupled to the housing, each flexure disk having an inner ring, an outer ring, and radial splines connecting the inner ring and the outer ring, and the mass being responsive to an acceleration, for providing a mass force that depends on the cooperation between the mass and the pair of flexure disks;

an optical fiber having a Bragg grating sensor; and

the Bragg grating sensor having a first end connected to the housing, having a second end connected to the mass of the proof mass means, and having a Bragg grating sensor arranged between the first end and the second end, the Bragg grating sensor being responsive to the mass force, and further responsive to an optical signal, for providing a Bragg grating sensor signal containing information about the acceleration.

32. An accelerometer, comprising:

a housing;

a main body having a mass slidably arranged in the housing, the mass being responsive to an acceleration, for providing a force; and

an optical fiber having a Bragg grating sensor that is coupled between the mass of the main body and the housing, responsive to the force, and further responsive to an optical signal, for providing a Bragg grating sensor signal containing information about the acceleration.

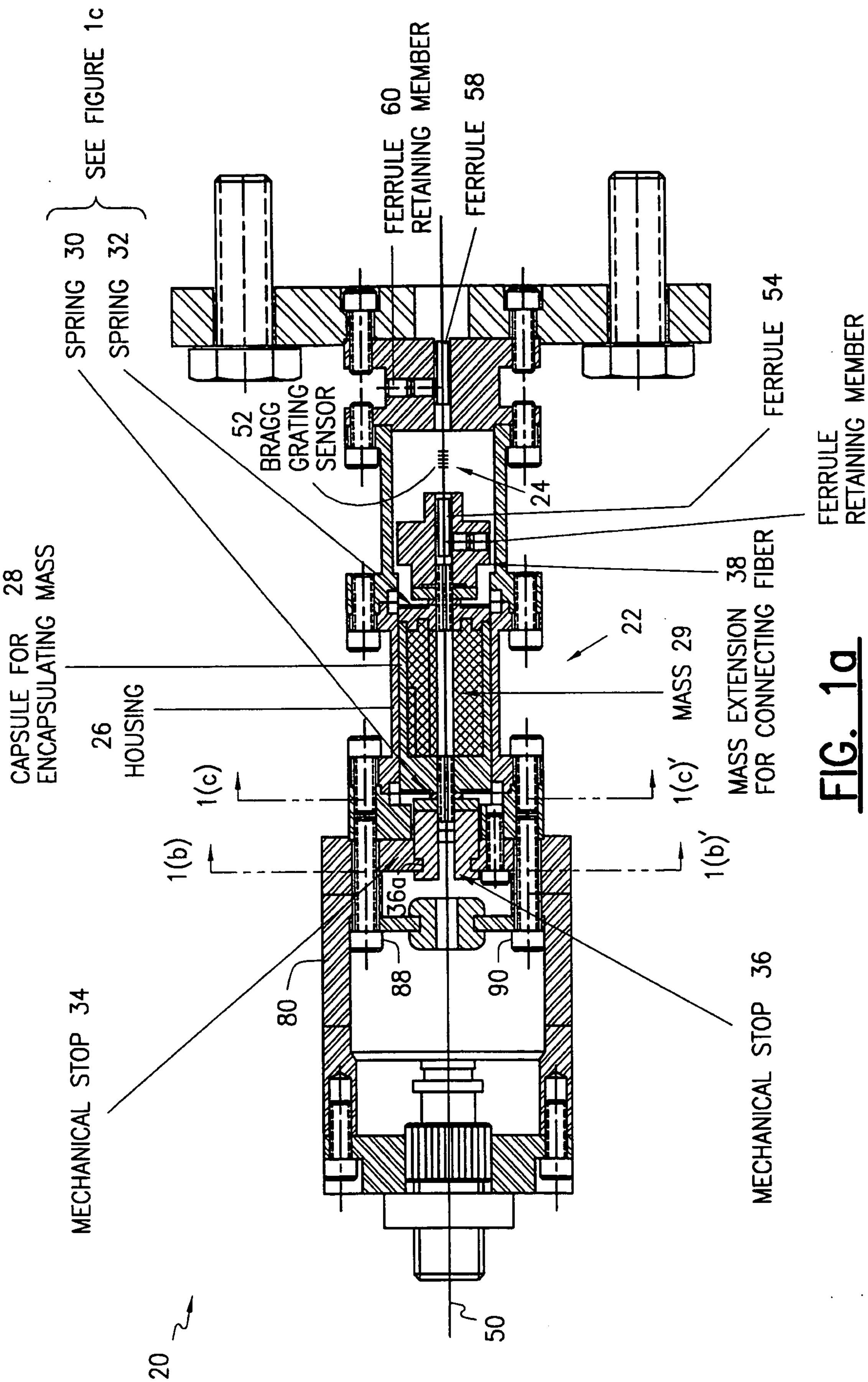

SEE FIGURE 1c
SPRING 30
SPRING 32
FERRULE 60
RETAINING MEMBER
FERRULE 58
52
BRAGG
GRATING
SENSOR
24
FERRULE 54
FERRULE
RETAINING MEMBER
38
MASS EXTENSION
FOR CONNECTING FIBER
22
MASS 29
CAPSULE FOR 28
ENCAPSULATING MASS
26
HOUSING
1(c)
1(c)'
1(b)
1(b)'
36a
88
90
80
MECHANICAL STOP 36
MECHANICAL STOP 34
50
20

FIG. 1a

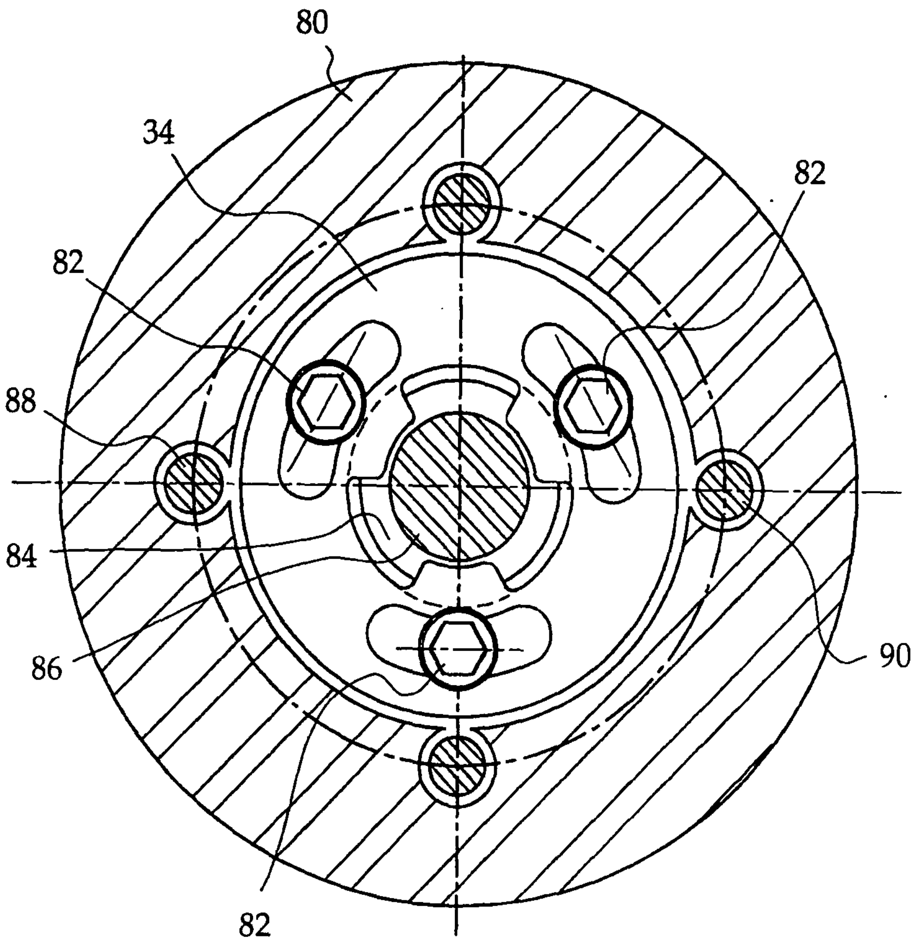

80
34
82
82
88
84
86
90
82

FIG. 1b

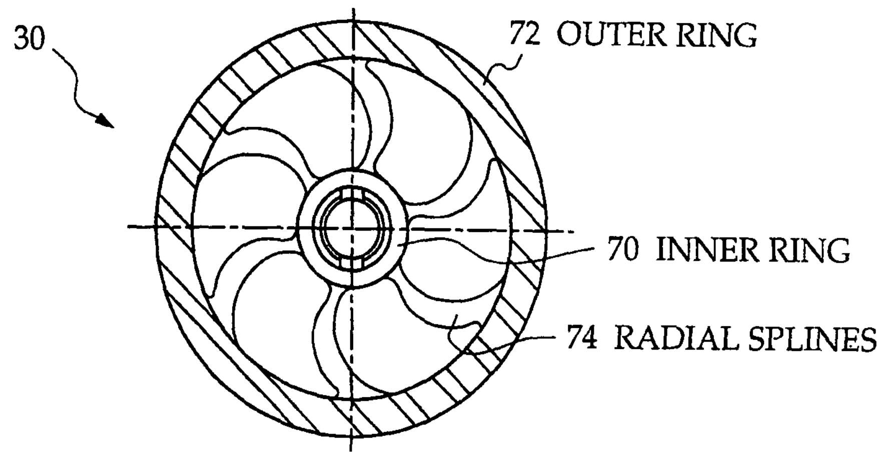

30
72 OUTER RING
70 INNER RING
74 RADIAL SPLINES

FIG. 1c

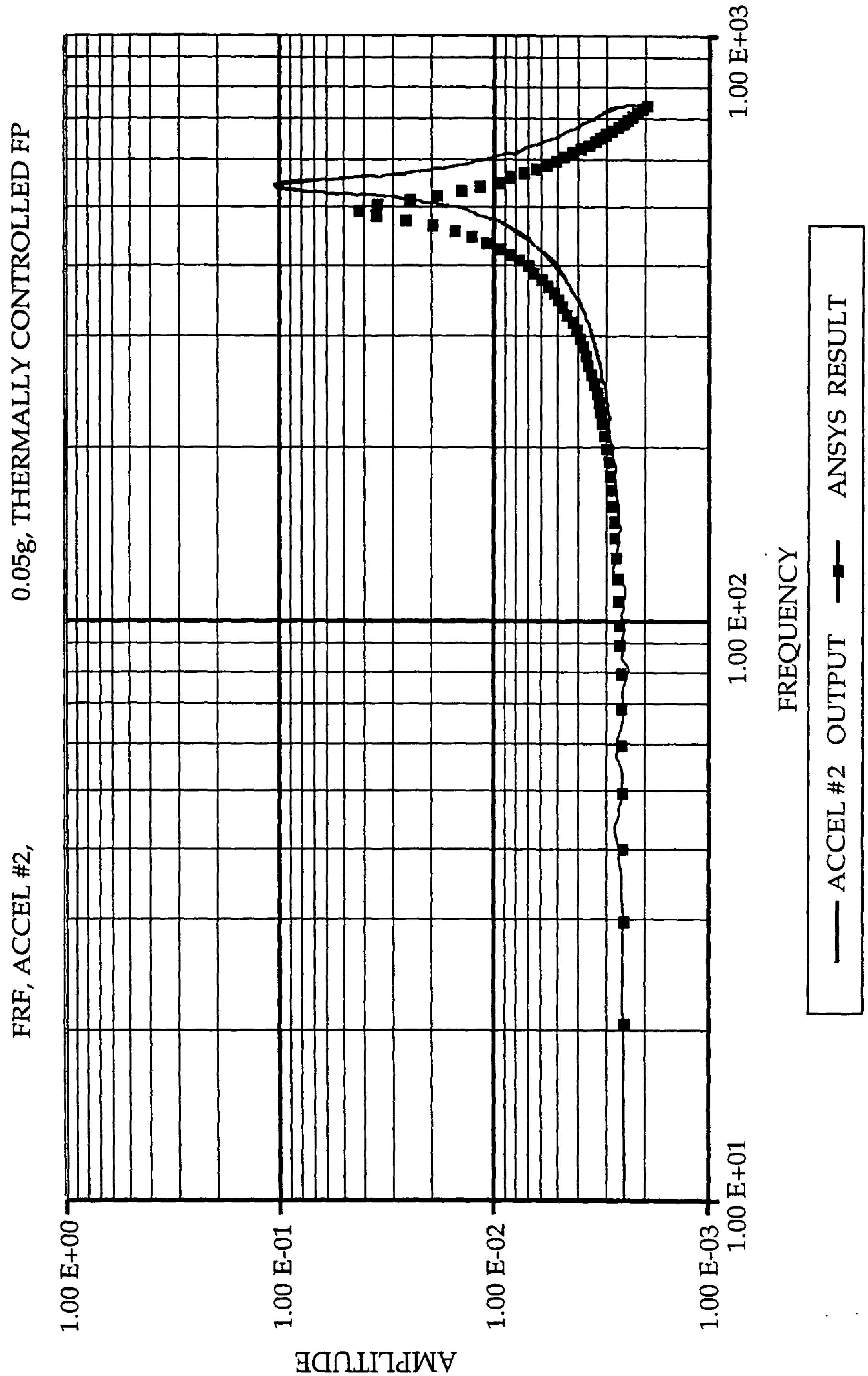

FRF, ACCEL #2, 0.05g, THERMALLY CONTROLLED FP
AMPLITUDE
1.00 E+00
1.00 E-01
1.00 E-02
1.00 E-03
FREQUENCY
1.00 E+01
1.00 E+02
1.00 E+03
ACCEL #2 OUTPUT
ANSYS RESULT

FIG. 1d

'Piston' Accelerometer

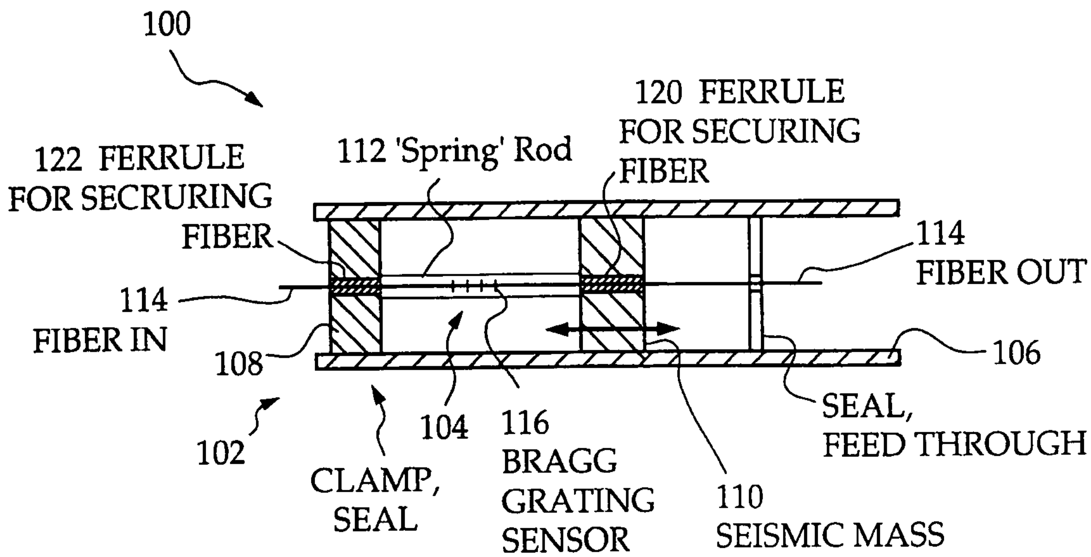


FIG. 2

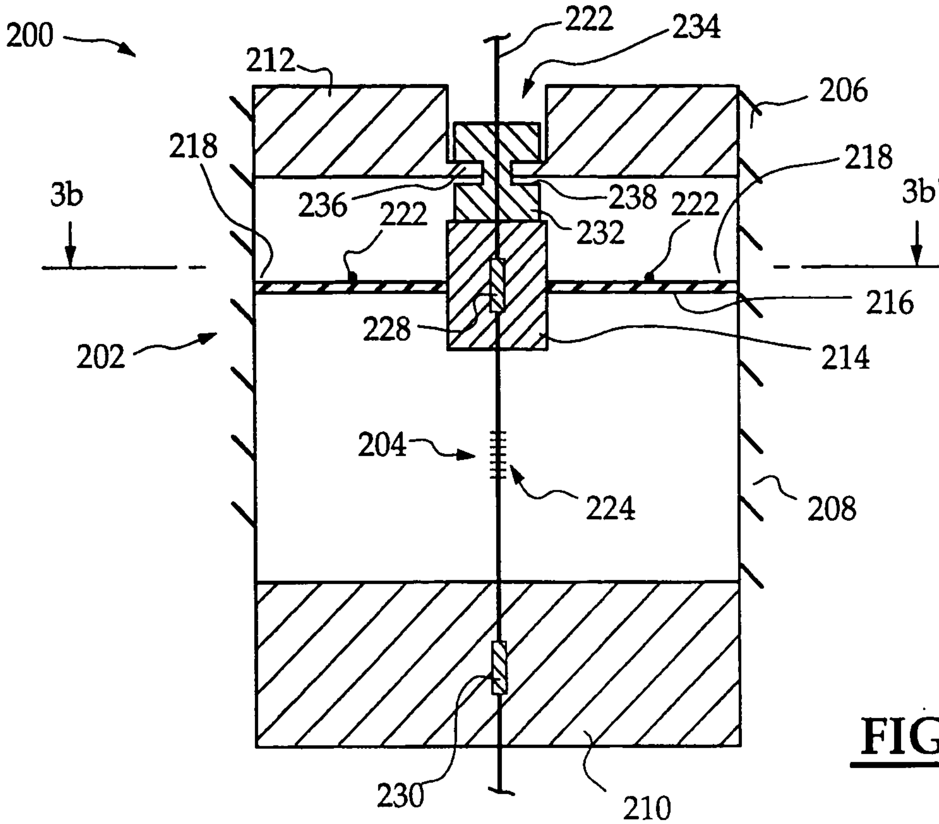

200
212
222
234
206
218
218
3b
236
238
222
232
222
3b'
216
228
214
202
204
224
208
230
210

FIG. 3a

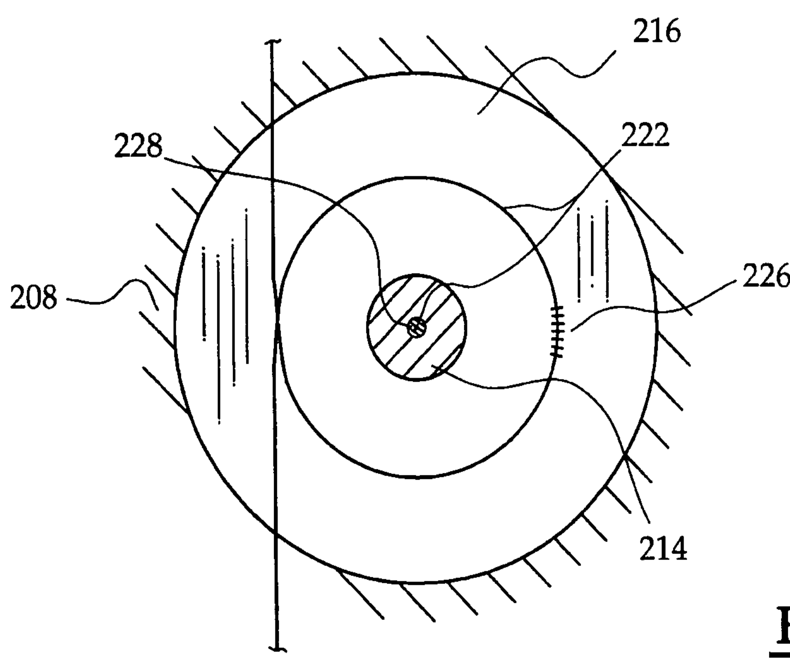

216
228
222
208
226
214

FIG. 3b

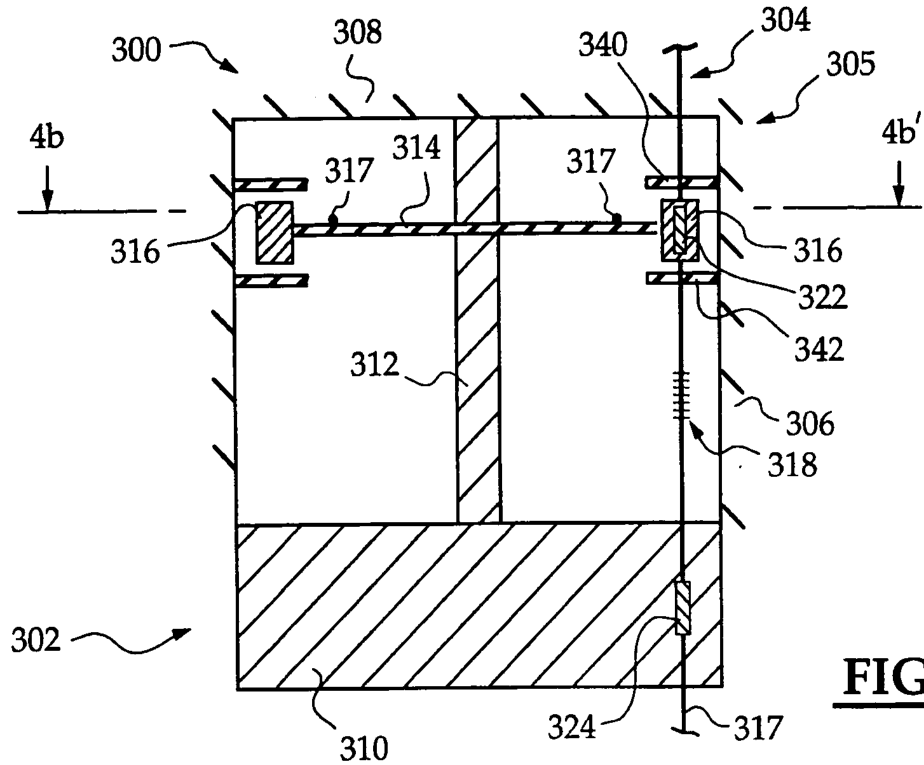

300
308
304
340
305
4b
4b'
317
314
317
316
316
322
342
312
306
318
302
310
324
317

FIG. 4a

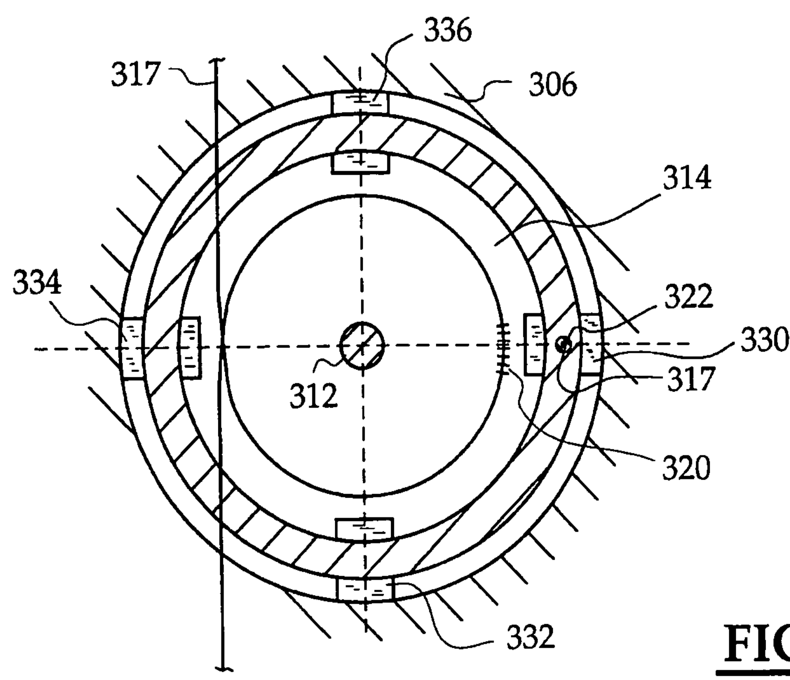

336
317
306
314
334
322
330
312
317
320
332

FIG. 4b

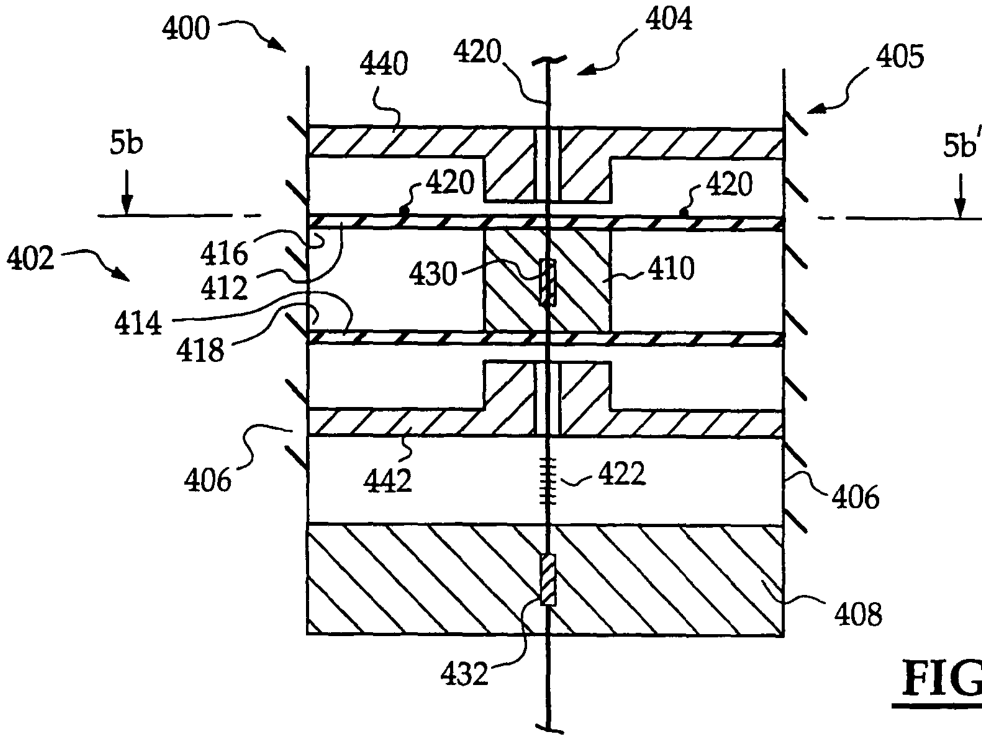

400
404
420
440
405
5b
5b'
420
420
402
416
412
430
410
414
418
406
442
422
406
408
432

FIG. 5a

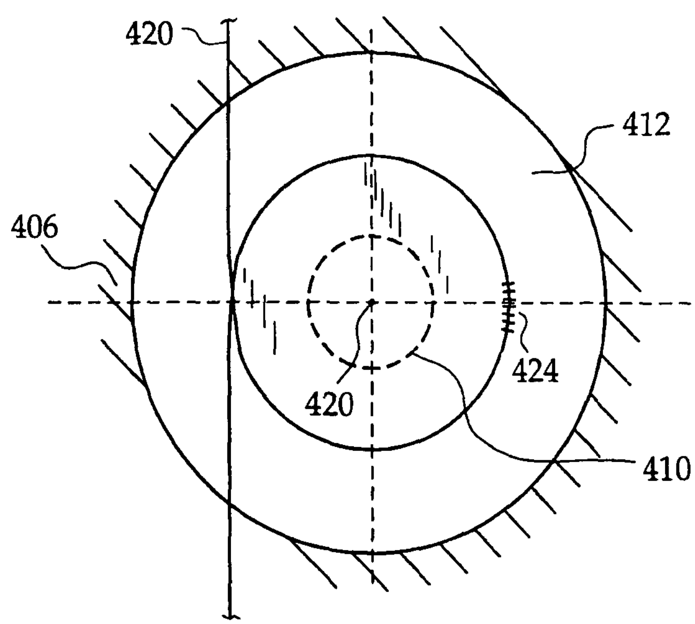

420
412
406
424
420
410

FIG. 5b

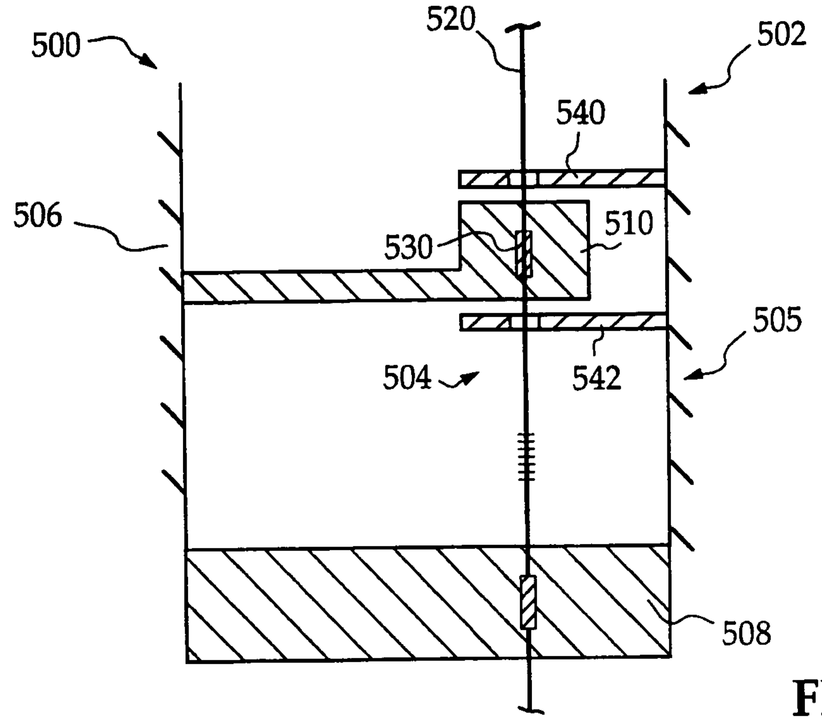


FIG. 6a

FIG. 6b

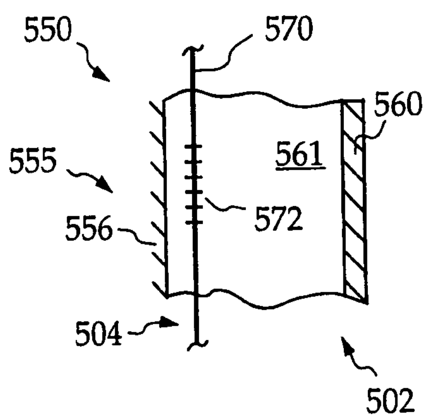
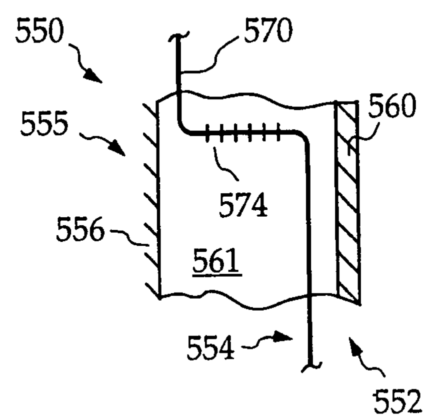


FIG. 6c



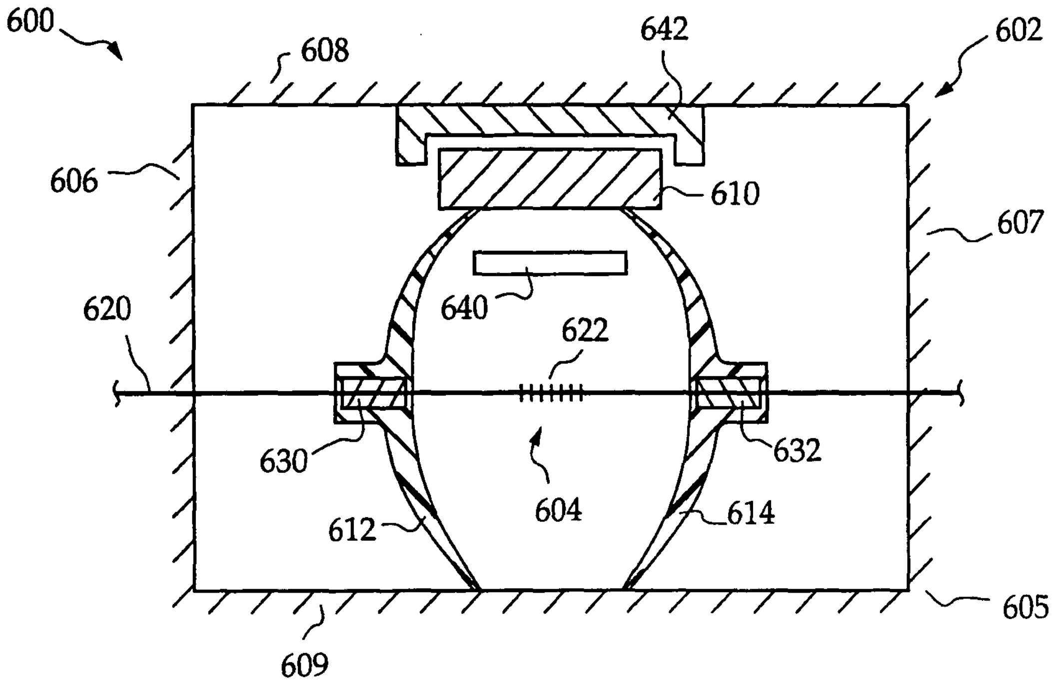

600
608
642
602
606
610
607
640
620
622
630
632
604
612
614
605
609

FIG. 7a

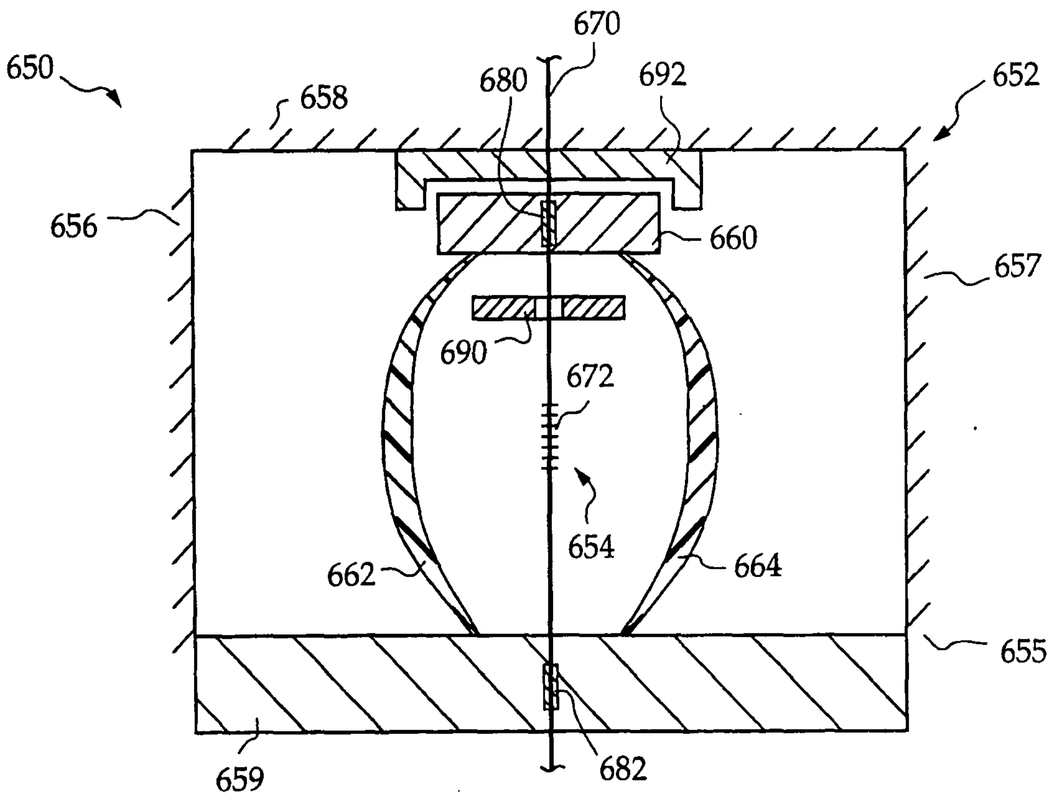

670
650
680
692
652
658
656
660
657
690
672
654
662
664
655
659
682

FIG. 7b

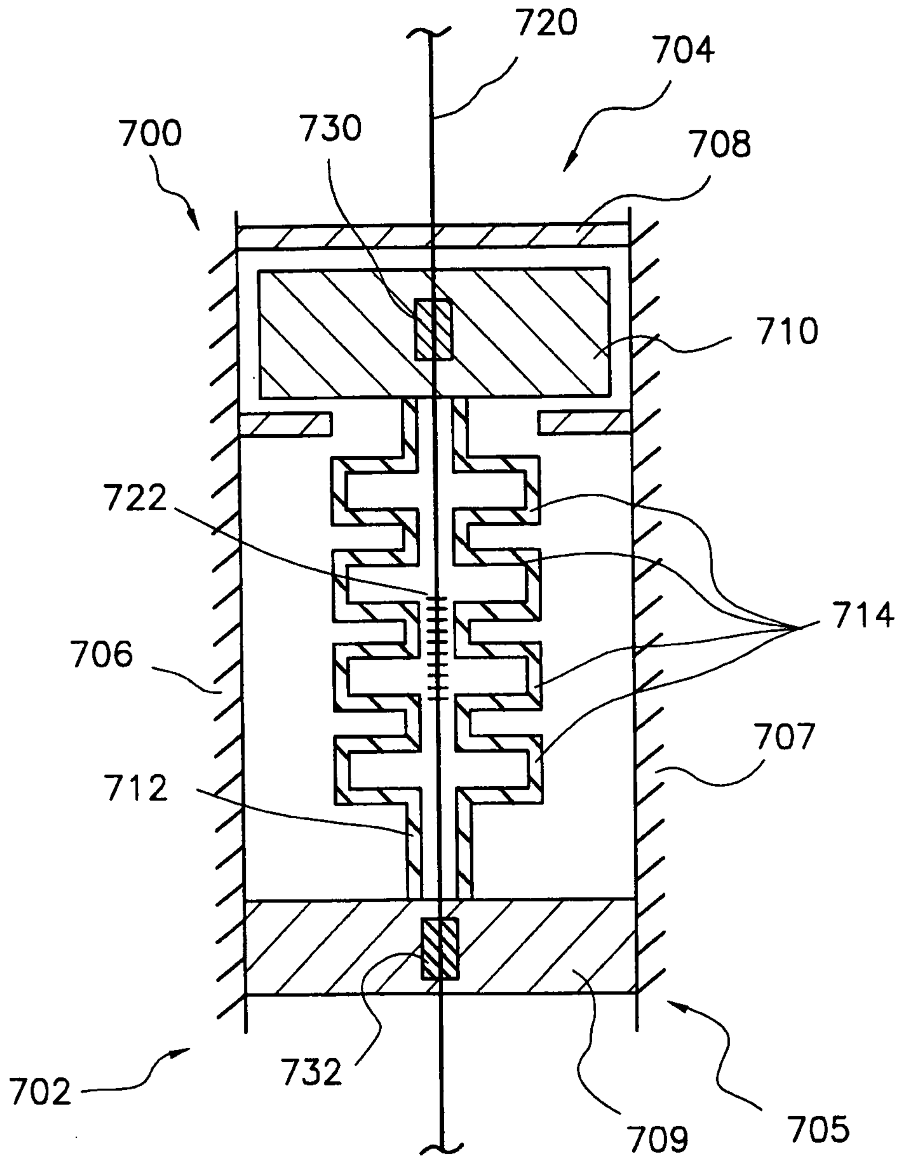
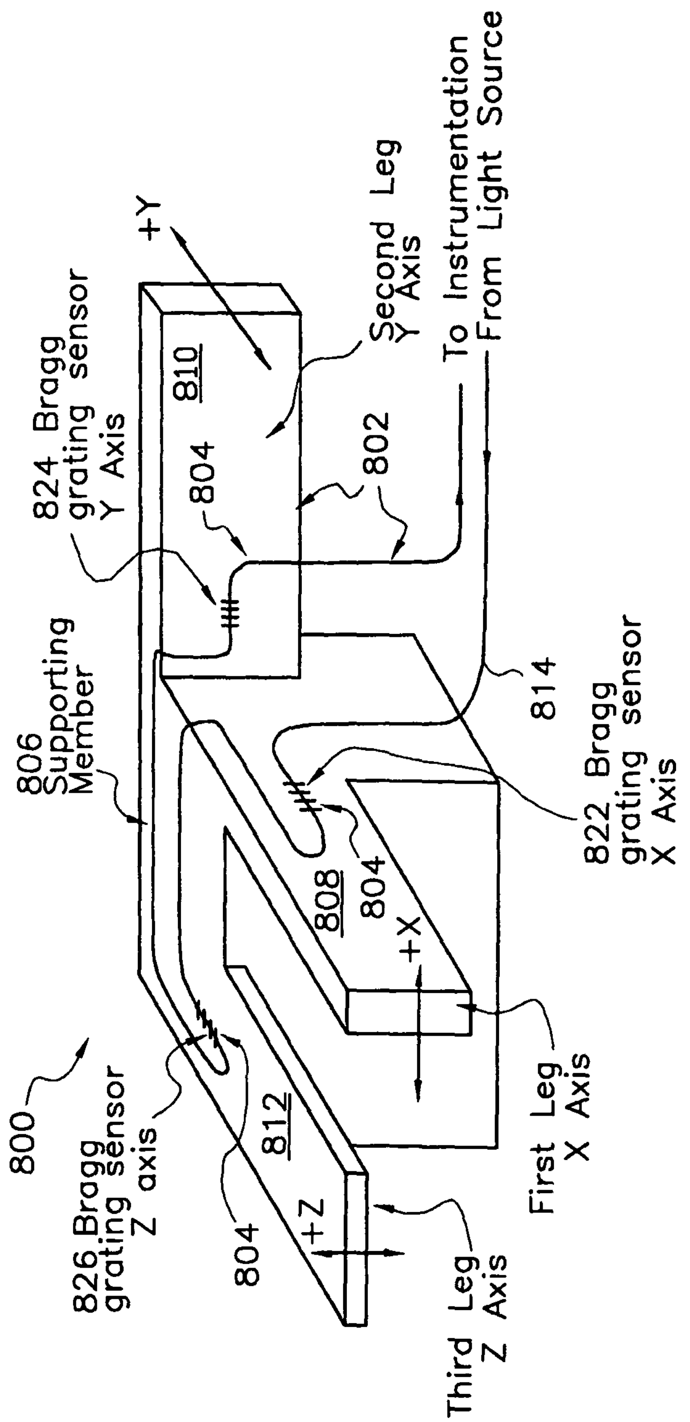


FIG. 8



+Y
824 Bragg grating sensor Y Axis
810
804
Second Leg Y Axis
802
To Instrumentation
From Light Source
806 Supporting Member
814
822 Bragg grating sensor X Axis
808
804
+X
First Leg X Axis
800
826 Bragg grating sensor Z axis
812
804
+Z
Third Leg Z Axis

FIG. 9

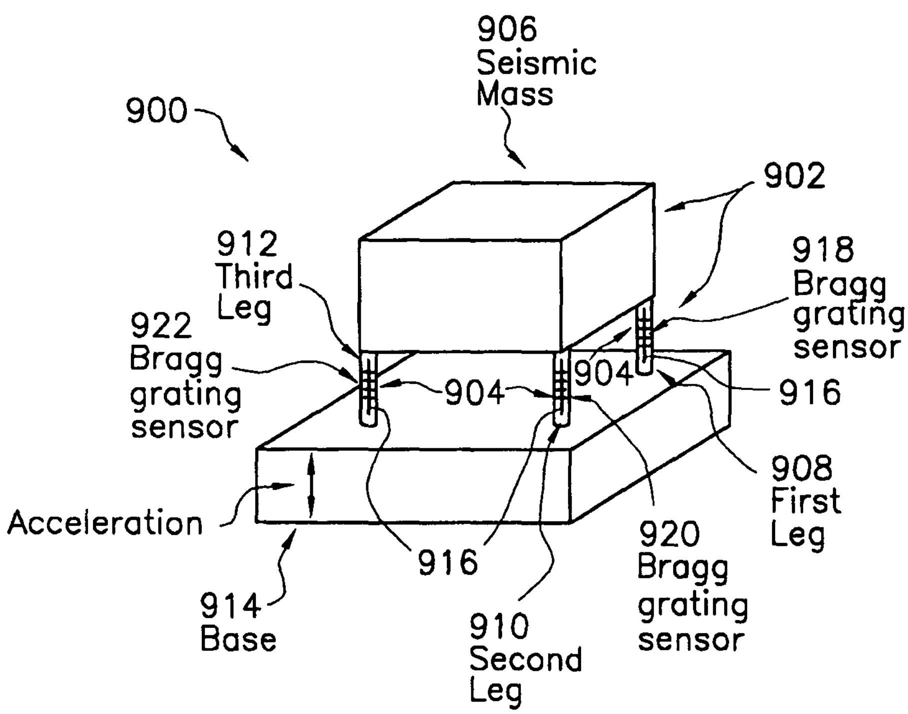

906
Seismic
Mass
900
902
912
Third
Leg
918
Bragg
grating
sensor
922
Bragg
grating
sensor
904
904
916
Acceleration
916
908
First
Leg
920
Bragg
grating
sensor
914
Base
910
Second
Leg

FIG. 10

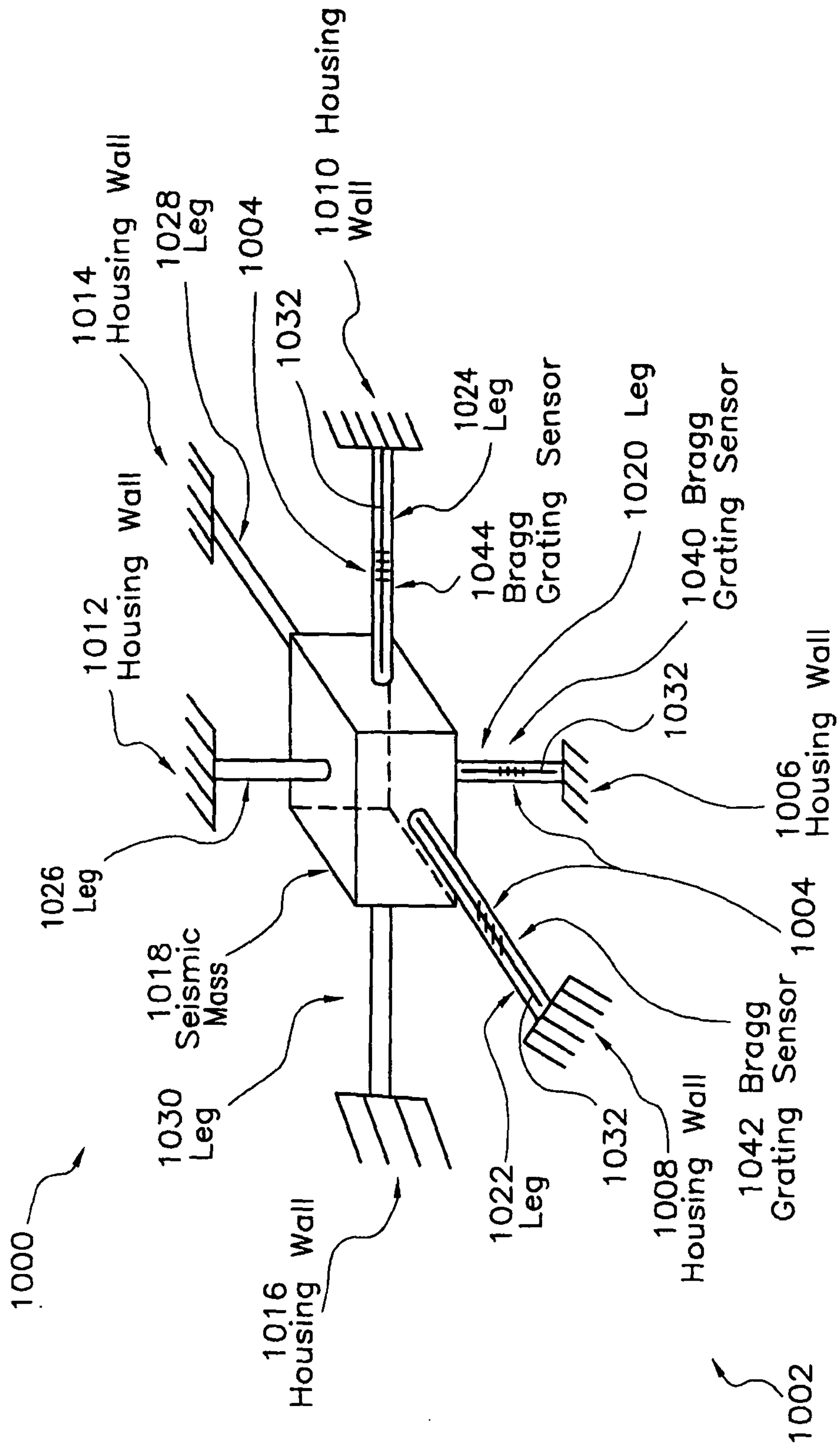

1000
1002
1004
1006 Housing Wall
1008 Housing Wall
1010 Housing Wall
1012 Housing Wall
1014 Housing Wall
1016 Housing Wall
1018 Seismic Mass
1020 Leg
1022 Leg
1024 Leg
1026 Leg
1028 Leg
1030 Leg
1032
1040 Bragg Grating Sensor
1042 Bragg Grating Sensor
1044 Bragg Grating Sensor

FIG. 11

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 99/01982

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G01P15/08 G01P15/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G01P

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	BERKOFF T A ET AL: "EXPERIMENTAL DEMONSTRATION OF A FIBEER BRAGG GRATING ACCELEROMETER" IEEE PHOTONICS TECHNOLOGY LETTERS, vol. 8, no. 12, 1 December 1996, pages 1677-1679, XP000679546	1-3,11, 12,32
Y	see the whole document	4

X	STORGAARD-LARSEN T ET AL: "OPTO-MECHANICAL ACCELEROMETER BASED ON STRAIN SENSING BY A BRAGG GRATING IN A PLANAR WAVEGUIDE" SENSORS AND ACTUATORS A, vol. A52, no. 1/03, 1 March 1996, pages 25-32, XP000599972 see page 25, line 1 - page 27, right-hand column, line 18; figures 1-3	1-3,11, 12,20

	-/--	

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 May 1999	07. 06. 99

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	PFLUGFELDER G.F.

2

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5 292 569 A (BARRY JOHN M ET AL) 8 March 1994 see the whole document	4

2

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 99/01982

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5292569 A	08-03-1994	NONE	